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PTO/SB/05 (4/98)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No. 2000-104

First Inventor or Application Identifier Khuy V. Nguyen

Title See 1 in Addendum

Express Mail Label No. EH757714502US

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APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ * Fee Transmittal Form (e.g., PTO/SB/17)
 (Submit an original and a duplicate for fee processing)
2. ☒ Specification [Total Pages 12] 1
 (preferred arrangement set forth below)
 - Descriptive title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. ☐ Drawing(s) (35 U.S.C. 113) [Total Sheets ☐] 1
4. Oath or Declaration [Total Pages 2] 1
 - a. ☒ Newly executed (original or copy)
 - b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))
 (for continuation/divisional with Box 16 completed)
 - i. ☐ DELETION OF INVENTOR(S)
 Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

5. ☐ Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
 - a. ☐ Computer Readable Copy
 - b. ☐ Paper Copy (identical to computer copy)
 - c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. ☒ Assignment Papers (cover sheet & document(s))
8. ☐ 37 C.F.R. § 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
9. ☐ English Translation Document (if applicable)
10. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
11. ☐ Preliminary Amendment
12. ☒ Return Receipt Postcard (MPEP 503)
 (Should be specifically itemized)
13. ☐ * Small Entity Statement(s) ☐ Statement filed in prior application (PTO/SB/09-12) Status still proper and desired
14. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
15. ☐ Other: _____

* NOTE FOR ITEMS 1 & 13 IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

16. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment.

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: _____

Prior application information: Examiner _____

Group / Art Unit: _____

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. CORRESPONDENCE ADDRESS

☐ Customer Number or Bar Code Label

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Signature		Date	4/2/00

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:
Khuy V. Nguyen, et al

Docket No. 2000-104

Application No.:

Group No.:

Filed:

Examiner:

For: SHUTDOWN BATTERY SEPARATOR MADE WITH
A BLEND OF POLYMER AND OLIGOMER

Assistant Commissioner for Patents
Washington, D.C. 20231

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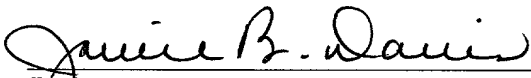
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Fee Transmittal (in duplicate)
Specification (12 pages)
Combined Declaration and Power of Attorney
Assignment Papers (cover sheet and document)
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Janice B. Davis

**SHUTDOWN BATTERY SEPARATOR MADE
WITH A BLEND OF POLYMER AND OLIGOMER**

Field Of The Invention

A shutdown separator for an electrochemical cell and the battery made therefrom are disclosed herein.

Background Of The Invention

In lithium ion rechargeable batteries, shutdown separators are used as part of the overall battery safety system. Specifically, there is a need, in these batteries, to prevent, or substantially reduce the likelihood of, thermal runaway which may arise from short circuiting caused by, for example, physical damage, internal defect, or overcharging. Shutdown separators, typically used in lithium ion rechargeable cells, will shutdown (i.e., sufficient pore closure to substantially stop ion or current flow within the cell) around 130°C (the approximate melting temperature of polyethylene).

Battery producers wish to have separators that shutdown at even lower temperatures for increased safety. To that end, several alternatives have been proposed, but none, apparently, have displaced the separators with 130°C shutdown. Those alternatives include multilayer separators having a particle

stretch membrane or a phase inversion membrane. Both have shutdown temperatures below 130°C.

Accordingly, there is an ongoing need for a low temperature shutdown separator.

Summary Of The Invention

The instant invention is directed to a battery separator including a microporous polyolefinic membrane having a porosity in a range of 30 - 80%, an average pore size in a range of 0.02 - 2.0 microns, and being made from a blend of a polyolefin polymer and an oligomer of a polyolefinic polymer.

Detailed Description Of The Invention

The instant invention is directed to a separator for a battery (or cell). The battery may be any battery that would benefit from the use of a separator having the ability to shutdown the ion (or current) flow between the battery's anode and cathode in response to a short circuit. An example of such a battery is a lithium battery, particularly a lithium ion rechargeable battery.

A battery typically comprises an anode, a cathode, a separator sandwiched between the anode and the cathode, an electrolyte in ionic contact with the anode and the cathode via the separator, and a package (e.g. a can or a foil bag) which

contains the anode, the cathode, the separator, and the electrolyte. For convenience, the invention will be described with reference to a lithium ion rechargeable cell having a liquid organic electrolyte, but the invention is not so limited.

The separator is a microporous membrane. It may be a single ply or multi-ply membrane. All separators should have sufficient mechanical strength to withstand the rigors of battery manufacture and battery use. Additionally, the separator should have sufficient thermal stability and shutdown capability. Thermal stability refers to the membrane's ability to substantially maintain its physical dimension during the abnormal conditions associated with thermal runaway (e.g. tolerable shrinkage at elevated temperature, and able to prevent physical contact of anode and cathode at elevated temperature). Shutdown capability refers to the membrane's ability to substantially close its pores, through which the electrolyte's ions conduct current flow between the anode and the cathode, as a result of thermal runaway. Shutdown should occur at a temperature of less than 130°C (this will be illustrated in greater detail below), and shutdown should occur sharply (e.g. the breadth of temperature response for shutdown is narrow, about 4-5°C).

In the case of the single ply separator, mechanical strength, thermal stability, and shutdown capability all reside in the single ply.

In the case of a multi-ply separator, two or more (preferably three) microporous membranes comprise the separator. Typically, at least one membrane provides sufficient mechanical strength and thermal stability, while another membrane provides the shutdown capability. A multi-ply separator may be made in any number of ways, but preferably by making individual membranes which are subsequently bonded together for example, by lamination (i.e., heat and/or pressure), or by coextrusion. In the former, individual membranes may be either microporous or non-porous prior to bonding. The microporous membranes having suitable thermal stability may be made, for example, by either a dry stretch or solvent extraction method. Such membranes are commercially available from, for example, Celgard Inc., Charlotte, North Carolina, Asahi Chemical Industry, Ltd., Tokyo, Japan, and Tonen Corporation of Tokyo, Japan. The microporous membrane having suitable shutdown capability is the instant invention.

The separator, e.g. for a lithium ion rechargeable battery, has a thickness less than 3 mils (75 microns) and, preferably, a thickness in the range of 3 to 75 microns and, most preferably, in the range of 5 to 37 microns. The separator has porosity in the range of 30 to 80%, preferably, in the range of 35 to 60%. The pore size is in the range of 0.02 to 2.0 microns, preferably, 0.04 to 0.5 microns. The separator has a Gurley Number of 1 to

150 seconds, preferably, 7 to 80 seconds. (Gurley number as used herein refers to the amount of time for 10 cc of air at 12.2 inches of water to pass through one square inch of membrane.)

The inventive microporous polyolefinic membrane is made from a blend of a polyolefin polymer and an oligomer of a polyolefinic polymer. Polymer, as used herein, refers to a long chain molecular structure in which the addition or deletion of monomers does not significantly impact its physical properties. An oligomer, as used herein, refers to a short chain polymer whose properties change with the addition or removal of the repeating units (or monomer). The oligomer does not have to be made from the same repeating units (or monomer) as the polymer. The polymer contemplated for use in the instant application refer to ones based on $C_1 - C_7$ repeating units (or monomer). Likewise, the oligomer contemplated for use herein refer to $C_1 - C_7$ based monomers. Polymers include polyethylene, polypropylene, polybutylene, and polymethylpentene. Polyethylene is preferred, and high density polyethylene (HDPE) is most preferred. The preferred oligomer includes polyethylene wax having a molecular weight of less than 6000. Most preferred is a polyethylene wax having a molecular weight in the range of 200 - 5600. The polymer and oligomer are blended (or mixed) together, so that the oligomer is uniformly distributed throughout the polymer. The blends may comprise less than 50% by weight oligomer, most

preferred are in the range of 2 - 40%. Oligomer is chosen so that it is easily blendable with the polymer.

Examples of the foregoing membranes are set forth below.

Examples

The following examples utilized the ingredients set out in Table 1. Percentage (%) refers to "weight percent" or "percent by weight."

Table 1

Polymer	Density	Melt Temperature (°C)	Percent Crystallinity
HDPE1 ¹	0.96	135	76
HDPE2 ²	0.96	134	78
Oligomer³			
PEWax 1500	0.96	119	100
PEWax 1000	0.96	111	93
PEWax 850	0.96	105	99
PEWax 725	0.95	101	89
PEWax 655	0.94	94	98
PEWax 600	0.94	89	95

¹ Fina 7208 commercially available from Fina Oil and Chemical Co. of Dallas, Texas.

² Escorene 7845 commercially available from Exxon Chemical Co. of Houston, Texas.

³ PEWax's are commercially available from Baker Petrolite Polymer Division Co. of Sugar Land, Texas.

Thirty percent by weight PEWax 1000 was hand mixed with 70% HDPE1. The blend was extruded at 190°C to form a film. The film

was annealed at 100°C for 10 minutes then stretched on an Instron at 95°C. The results are set out in Table 2.

Table 2

	Thickness (mil)	Gurley (sec)	Porosity (%)	Shutdown Temperature (°C)
100% HDPE1	0.64	54	30	130
Blend	0.50	45	35	121

Thirty percent (30%) oligomer/70% polymer blend films are made by an extrude/anneal/stretch (i.e., dry stretch) process. The results are set out in Table 3.

Table 3

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
100% HDPE1	0.65	21	130
30% PEWax 1000/70% HDPE1	0.47	13	115
30% PEWax 1000/70% HDPE1	0.60	14	117
100% HDPE2	0.82	42	130
30% PEWax 1000/70% HDPE2	0.88	25	116
30% PEWax 1000/70% HDPE2	0.96	34	118

The effect of different concentrations of oligomer on the blend are set in Table 4.

Table 4

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
10% PEWax 1000/90%HDPE1	0.78	22	125
20% PEWax 1000/80% HDPE1	0.70	31	123
30% PEWax 1000/70% HDPE1	0.52	24	122
40% PEWax 1000/60% HDPE1	0.58	33	121

The effect of oligomer variants on shutdown temperature are set out in Table 5.

Table 5

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
30% PEWax 1500/70% HDPE1	0.57	13	124
30% PEWax 1000/70% HDPE1	0.70	31	122
30% PEWax 725/70% HDPE1	0.92	42	122
30% PEWax 600/70% HDPE1	0.64	19	120

The effect of multi-component oligomers on shutdown temperature are set out in Table 6.

Table 6

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
15/15 PEWax 725/850/70% HDPE1	0.85	44	123
10/10/10 PEWax 655/725/1000/70% HDPE1	0.46	18	123
10/10/10/10 PEWax 655/725/850/ 1000/60%HDPE1	0.52	24	119

A 30% PEWax 1000 and 70% HDPE2 blend was extruded, annealed, and stretched to obtain:

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
30% PEWax 1000/70% HDPE2	1.06	20	119

A polypropylene/polyethylene/polypropylene (i.e., 8 microns thick polypropylene) trilayer (like Celgard 2300) was made except the center layer was replaced with a 30% PEWax 1000/70% HDPE1 blend to obtain:

	Thickness (mil)	Gurley (sec)	Shutdown Temperature (°C)
Trilayer	0.93	44	125

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicating the scope of the invention.

In The Claims:

1. A battery separator comprising:
a microporous polyolefinic membrane having a porosity in a range of 30 - 80%, an average pore size in a range of 0.02 - 2.0 microns, and being made from a blend of a polyolefin polymer, and an oligomer of a polyolefinic polymer.
2. A battery separator comprising
a microporous polyolefinic membrane having a porosity in a range of 30 - 80%, an average pore size in a range of 0.02 - 2.0 microns, and being made from a blend of a C₁ - C₇ based polymer and a C₁ - C₇ based oligomer.
3. The separator according to Claims 1 or 2 wherein said separator having a shutdown temperature less than the melting temperature of said polymer.
4. The separator according to Claims 1 or 2 wherein said separator having a thickness less than 3 mils.
5. The separator according to Claims 1 or 2 wherein said membrane being one layer of a multilayered separator.
6. The separator according to Claims 1 or 2 wherein said blend having 50% or less by weight of oligomer.

7. The separator according to Claims 1 or 2 wherein said polymer being a polyethylene.

8. The separator according to Claims 1 or 2 wherein said oligomer being a polyethylene wax having a molecular weight less than 6000.

9. A battery separator for a lithium rechargeable battery comprising a microporous polyolefinic membrane having a shutdown temperature of less than about 130°C, a porosity in a range of 30 - 80%, an average pore size in a range of 0.02 - 2.0 microns, and being made from a blend of a high density polyethylene polymer and a polyethylene wax having a molecular weight less than 6000.

10. A battery comprising:

an anode;

a cathode;

a separator according to Claims 1 or 2, said separator being disposed between said anode and said cathode; and

an electrolyte in ionic communication with said anode and said cathode via said separator.

11. The battery according to Claim 10 being a lithium battery.

ABSTRACT

The instant invention is directed to a battery separator including a microporous polyolefinic membrane having a porosity in a range of 30 - 80%, an average pore size in a range of 0.02 - 2.0 microns, and being made from a blend of a polyolefin polymer and an oligomer of a polyolefinic polymer.

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COMBINED DECLARATION AND POWER OF ATTORNEY

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am a joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: "SHUTDOWN BATTERY SEPARATOR MADE WITH A BLEND OF POLYMER AND OLIGOMER".

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations § 1.56(a).

As a named inventor, I hereby appoint the following attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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